iMedPub Journals http://journals.imed.pub

Vol. 4 No. 4:4 doi: 10.3823/761

2014

Antibiotic resistance and its association with biocide susceptibilities among microbial isolates in an Egyptian hospital

Abstract

Background: Recently, there has been a growing concern that the indiscriminate use of antimicrobial agents in household, food industry and hospitals may contribute to the emergence of bacteria resistant to antibiotics.

Aim of the work: To detect any possible link between the susceptibility profiles of different clinical and environmental isolates to biocides and antibiotics in an Egyptian hospital.

Methods: Sixty six different microbial isolates were isolated from different clinical specimens and different environmental samples obtained from a University Hospital in Alexandria. These isolates were screened for their susceptibility to 22 broad spectrum antibiotics using disc agar diffusion technique. In addition, the susceptibility of the isolates to six commonly used biocides was screened through minimum inhibitory concentration (MIC) determination by agar dilution technique. Correlations between the obtained data were made through Spearman's correlation using SPSS[®] statistical program.

Results: Sixty two percent of the isolates were multidrug resistant (MDR); and 11% were extremely drug resistant (XDR). On the other hand, 34% of the tested isolates were multi-disinfectant reduced susceptibility (MDRS) isolates. The statistical analysis of our data revealed a moderate positive correlation between antibiotic resistance and biocide tolerance (0.376≥; ρ ≥0.278; p<0.05). In addition, strong significant correlations (p<0.01) were also found between reduced susceptibilities

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to multiple biocides such as benzalkonium chloride (BK), cetrimide (CET), chlorhexidine (CHX), povidone-iodine (PVPI) and Dettol[®].

Conclusion: The observed association between antibiotic resistance and biocides reduced susceptibility may reflect cross-resistance between biocides and antibiotics used in hospital.

Keywords: Cross-resistance, Correlation, Biocides, Antibiotics, Noso-comial Infections.

Introduction

Nosocomial infections are recognized as a serious patient safety issue worldwide; especially with the alarming increase in bacterial resistance to most of the existing antibacterial agents [1]. The World Health Organization (WHO) considered healthcareassociated infections to be a major problem of hospital treatment which is contributing significantly to morbidity and mortality rates and cost of care [2].

Biocides (antiseptics and disinfectants) are used extensively in hospitals and other healthcare settings for a variety of topical and hard-surface applications. They are an essential part of infection control practices and aid in the prevention of nosocomial infections [3].

Biocides used in hospital settings belong to different chemical classes. Those based on quaternary ammonium compounds (QACs) such as benzalkonium chloride (BK) and cetrimide (CET) are used for preoperative skin disinfection and non-critical surface disinfection. Chlorhexidine (CHX) which belongs to biguanides is extensively used as an ingredient in multiple antiseptic and disinfectant products especially in combination with QACs such as in savlon antiseptic liquid [4, 5].

Among the other commonly used classes of biocides are the oxidizing agents such as the chlorine releasing agents (CRA) and povidone iodine (PVPI). Sodium hypochlorite (household bleach) is widely used in hospitals as general disinfectants; especially for the disinfection of blood spillages. Povidone iodine (Betadine[®]) is the most extensively used antiseptic in the Egyptian hospitals for surgical hand disinfection and preoperative skin disinfection [3, 4].

Chloroxylenol which is a phenolic compound is the main chemical constituent of the commercial product Dettol[®] which is widely used in homes and healthcare settings for various purposes including disinfection of the skin, objects and equipment as well as environmental surfaces [6].

In spite of the extensive use of biocides in hospitals, the incidence of nosocomial infections has not decreased, and many outbreaks have been caused by multidrug-resistant pathogens [7]. Many reports on microbial adaptation and resistance to biocides have been emerging [1, 8]. Therefore, there has been a growing concern in the recent years that, as for antibiotics, intensive exposure of hospital pathogens to biocides might result in the emergence of resistance to these agents [1].

It is well established that the main cause of the development and spread of antibiotic resistance within hospitals is the inappropriate widespread use and over-prescription of antibiotics in clinical practice [9]. However, concern has been expressed that the indiscriminate use of biocides in general practice and especially in the clinical settings may be another

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contributing factor to the evolution and selection of antibiotic resistant strains [1, 3, 4, 10, 11].

This study aimed to investigate the relationship between biocide use and antibiotic resistance among common bacteria species in the Egyptian hospitals.

Material and Methods

The protocol of this study was approved by the Council of Postgraduate studies in Faculty of Pharmacy and in Alexandria University, Egypt.

Microorganisms Standard strains

The standard strains used in this study were:

Staphylococcus aureus ATCC 6538, S. aureus ATCC 12600, Staphylococcus epidermidis ATCC 12228, Escherichia coli ATCC 8739, E. coli NCTC 10418, Enterococcus faecalis ATCC 29212, Klebsiella pneumoniae ATCC 13883, Pseudomonas aeruginosa ATCC 9027, Candida albicans ATCC 10231, Micrococcus luteus ATCC 9341.

Bacterial isolates

A total of 66 bacterial isolates were included in this study. These were classified into:

Clinical isolates

Forty-one clinical isolates were collected from different clinical specimens: infected surgical wounds, sputum, blood, pus, infected bed sores, urine, infected leg ulcer and inter costal tube drainage. The isolates were obtained from inpatients who acquired nosocomial infections in the intensive care unit (ICU), the high dependency unit (HDU); and wards in the main University Hospital, Faculty of Medicine, Alexandria University by the help of the medical staff.

The clinical isolates were classified into 27 Gram negative and 14 Gram positive strains. These were identified by classical microscopy and biochemical methods as follows: 14 Pseudomonas aeruginosa, 5 Acinetobacter baumannii, 1 E. coli, 6 Klebsiella spp., 1 Proteus mirabilis, 6 S. aureus, 5 S. epidermidis, 2 E. faecalis and 1 E. faecium.

Environmental isolates

A total of 25 environmental isolates were also included in this study. These were isolated from different samples obtained from the hospital environment. Samples were collected from settle plates placed in: the operation theatre of emergency department, the HDU, and the operation theatre of the surgery department. In addition, swabs were taken from the surface of the dressing table, the sink in the HDU, and the bacterial filtration of chlorine waste solution used for disinfection of the wards. The environmental isolates were classified into 11 Gram-negative and 14 Gram-positive organisms. These were identified at least to the genus level using Gram-stain microscopy and biochemical methods as follows: 8 Acinetobacter spp., 3 Klebsiella spp., 3 S. aureus, 6 coagulase negative staphylococci (CoNS), 2 Micrococcus spp., 2 Gram positive rods and 1 C. albicans. The E. coli, P. mirabilis and all Klebsiella spp. Isolates were grouped as Enterobacteriaceae. Also, all staphylococci isolates which showed coagulase-negative test were grouped as non-coagulase staphylococci (CONS). This group included the clinical S. epidermidis isolates.

Culture media

Nutrient agar and broth (LAB M Ltd, UK), Müller -Hinton agar and broth (LAB M Ltd, UK)

Biocides

Benzalkonium chloride powder (Pharco pharmaceutical Co., Egypt), Cetrimide (Alexandria Co. for Pharmaceuticals, Egypt);, Chlorhexidine diacetate (Synochem Präparate, Germany), Chlorine releasing agent was purchased as Clorox[®] which contains 5% sodium hypochlorite (Clorox Co., Egypt),

Dettol[®] which contains Chloroxylenol BP 4.8% w/v (Royal Cosmetic Co., Reckitt Benckiser, Egypt), Povidone lodine was purchased as Betadine[®] (10%) (Nile Pharm. and Chem. Ind. Co., Egypt).

Antibiotics

All antibiotic discs were obtained from BIOANAL-YSE, Turkey.

Amikacin (AK), ampicillin/sulbactam (SAM), aztreonam (ATM), carbenicillin (PY), cefepime (FEP), cefoperazone (CEP), cefotaxime (CTX), ceftazidime (CAZ), ceftriaxone (CRO), cephradine (CE), cefuroxime (CXM), chloramphenicol (C), ciprofloxacin (CIP), doxycycline (DO), erythromycin (E), gentamicin (CN), imipenem (IPM), levofloxacin (LEV), lincomycin (L), oxacillin (OX), rifampin (RA), tetracycline (TE), vancomycin (VA).

Isolation of microorganisms from air by passive air sampling techniques using settle plates

Three sterile and pre-incubated nutrient agar plates with a diameter of 9 cm each were left open exposed to air to collect aerobic microorganisms in air which sediment out on the surface of the agar plates. One plate was placed in each of the following mentioned places: the HDU, an operation theatre in the Surgery department; and an operation theatre in the Emergency department. The settle plates in operation theatres were placed during operation according to 1/1/1 scheme (for 1 hr, 1 m above the floor, about 1 m away from walls or any major obstacles) [12]. The plates were then closed and sent immediately to the laboratory to be incubated at 37°C for 48 hr.

Determination of the MICs of different biocides

The MICs of 6 biocides: BK, CHX, CET, hypochlorite solution Clorox[®], PVPI (Betadine[®]) and Dettol[®] were screened for the clinical and environmental isolates using the agar dilution technique [13]. The MIC₅₀ and MIC₉₀ were calculated for each class of tested isolates using the cumulate and interpolate method according to Hamilton-Miller [14]. The isolates showing MIC values higher than the MIC₅₀ were assumed to have disinfectant reduced susceptibility (DRS) isolates. The isolates showing reduced susceptibility to more than two biocides were considered as multiple disinfectant reduced susceptibility (MDRS) isolates

Antibiotic susceptibility testing of the isolates

The susceptibility of the potentially pathogenic isolates to various commonly used broad spectrum antibiotics was determined by the standard disc agar diffusion technique according to Bauer *et al.*[15] with some modifications [16]. The susceptibilities of the tested isolates were compared to the susceptibility tables published in the Clinical and Laboratory Standards Institute (CLSI 2007) and the British Society of Antimicrobial Chemotherapy (BSAC version 10) [16, 17]. The isolates were classified into MDR and XDR according to the published international expert proposal for standard definitions for acquired resistance profiles [18].

Statistical analyses

The obtained data were analyzed using the statistical program SPSS version 20 (IPM Co., NY, USA). The correlations between MIC values for each pair of the studied biocides; in addition, the correlations between the MIC values of each biocide and the percentage of the resistant antibiotics in all isolates were determined using Spearman rank correlation [19]. The correlation was considered significant when the P-value is less than 0.05.

doi: 10.3823/761

Results

Antibiotic resistance patterns

Sixty-two percent of the tested isolates were MDR and 11% were XDR [18]. The clinical isolates were found to be more resistant to antibiotics than the environmental isolates (**Figures 1 and 2**).

Cefotaxime and ceftriaxone were the least active antibiotics against the Gram-negative isolates followed by ampicillin/ sulbactam and tetracycline (the percentages of resistant isolates were 92.6%, 92.6%, 89% and 85%, respectively). Whereas, the most active antibiotic against the clinical Gramnegative isolates was imipenem (the percentage of resistant isolates was 26%) (**Figure 1**).

In general, the antibiotics which percentage of resistant isolates exceeded 50% were aztreonam, chloramphenicol, ceftazidime, cefoperazone, ciprofloxacin, gentamicin, ceftriaxone, cefotaxime, doxycycline, cefepime, carbenicillin, ampicillin/sulbactam and tetracycline for the clinical Gram-negative isolates. The corresponding antibiotics for the environmental Gram-negative isolates were ceftriaxone, cefotaxime, carbenicillin and ampicillin/sulbactam (**Figure 1**).

Similarly, the environmental *Staphylococcus* isolates were less resistant to antibiotics than the clinical isolates (**Figure 2**). The percentage of oxacillin resistance among the clinical staphylococci isolates was about 90.9% versus 44.4% among the environmental isolates. No vancomycin resistance was observed among the tested isolates. It can be noticed that ceftazidime, cefotaxime and ceftriaxone were the least active antibiotics against the clinical Gram-positive isolates followed by oxacillin and cefotaxime; the percentage of resistant isolates were 100%, 100%, 100%, 92.9% and 92.9% respectively.

In general, the antibiotics which percentage of resistant isolates exceeded 50% were ceftazidime, gentamicin, ceftriaxone, cefotaxime, doxycycline, erythromycin, cefepime, lincomycin, oxacillin and tetracycline for the clinical Gram-positive isolates. The corresponding antibiotics for the environmen-



Figure 1. Frequency of antibiotic resistance among the Gram negative isolates. The dashed line indicates resistance among 50% of the tested isolates. Cl: Clinical isolates. Env: Environmental isolates.

THE INTERNATIONAL ARABIC JOURNAL OF ANTIMICROBIAL AGENTS ISSN 2174-9094

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Figure 2. Frequency of antibiotics resistance among the Gram positive isolates. The dashed line indicates resistance among 50% of the tested isolates. Cl: Clinical isolates. Env: Environmental isolates.

tal Gram-positive isolates were ceftazidime, gentamicin, ceftriaxone, cefotaxime, and erythromycin (**Figure 2**).

The susceptibilities of the collected isolates to the tested biocides

In order to determine the relative susceptibilities of the collected clinical and environmental isolates to the tested biocides, the MIC values of the tested isolates were compared to those obtained for the corresponding standard strains which were used as control (**Table 1**).

It can be noticed from the MIC ranges presented in **Table 2** that the Gram-negative isolates were much more insusceptible to BK, CHX, CET and Dettol[®] than the Gram- positive ones. On the other hand, there was no considerable difference in the susceptibilities of Gram-positive and Gram-negative isolates towards CRA (Clorox[®]) and PVPI (Betadine[®]), however, the Gramnegative isolates were slightly more insusceptible towards PVPI. In General, it was noticed that the source of the isolates; whether being clinical or environmental, did not significantly influenced the susceptibility to biocides within the same class of organisms. It was also noticed that *P. ae-ruginosa* and some *A. baumannii* clinical isolates were the most insusceptible organisms towards multiple biocides; BK, CHX and CET. The MIC_{50} and MIC_{90} was calculated for each class of tested isolates according to the cumulate and interpolate method and were listed in **Table 2** [14]. About 32% of the tested Gram negative isolates were considered MDRS isolates.

Correlation between the MIC values of biocides and the percentage of resistant antibiotics

The MICs of BK for each isolate were correlated with those of CET. The obtained Spearman's correlation coefficient (ρ 0.951, N=66) which was significant at 0.01 level indicated very strong correlation between the two QACs; BK and CET. Very strong significant correlations were also found between the MIC values of the following pairs of biocides: BK and CHX (ρ 0.801, p<0.01, N=66); CET and CHX (ρ 0.801, p<0.01, N=66); BK and PVPI (ρ 0.811, p<0.01, N=66).

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Standard Studies	MIC (mg/L)					
Standard Strains	BK	CHX	CET	CRA	PVPI	Dettol
P. aeruginosa ATCC 9027	100	12.5	100	937.5	1250	150
K. pneumoniae ATCC 13883	50	12.5	50	625	2500	150
E. coli ATCC 8739	50	3.125	50	625	2500	150
E. coli NCTC 10418	50	4.68	50	937.5	2500	150
S. aureus ATCC 6538	1.56	1.56	1.56	1250	1250	37.5
S. aureus ATCC 12600	3.125	1.56	3.125	1250	1250	37.5
S. epidermidis ATCC 12228	0.78	1.56	0.78	625	1250	75
M. luteus ATCC 9341	0.78	1.56	1.56	156.25	1250	37.5
E. faecalis ATCC 29212	6.25	3.125	4.7	234.4	937.5	37.5
C. albicans ATCC 10231	6.25	3.125	3.125	1250	1250	37.5
Acinetobacter spp. (A)*	25	10	ND	ND	ND	ND

Table 1. The MICs of biocides against the standard strains*

The average MICs of BK and CHX for Acinetobacter spp. published in the literature [20]. ND: Not determined.

Table 2. The ranges of MIC values, MIC_{50} and MIC_{90} for the different classes of tested isolates (categorization was based on the MIC_{50})

Biocides	Range of MICs (mg/L) (MIC ₅₀ / MIC ₉₀)							
Organisms	BK	СНХ	CET	CRA	PVPI	Dettol®		
Pseudomonas spp.	75->400*	6.25->200	75->400	312.5-1250	1250-2500	150-300		
	(200/400)**	(12.5/25)	(200/400)	(625/125)	(2500/2500)	(150/300)		
Acinetobacter spp.	12.5->400	1.56-150	6.25-400	234.4-625	1250-2500	37.5-150		
	(25/400)	(12.5/50)	(50/400)	(312.5/625)	(1250/2500)	(75/150)		
Enterobacteriaceae	25-200	3.125-50	25-200	625-1250	1250-3750	37.5-150		
	(50/200)	(25/50)	(75/200)	(937.5/1250)	(2500/2500)	(150/150)		
S. aureus	1.56-12.5	1.56-3.125	3.125-6.25	468.75-1875	625-1250	18.75-75		
	(3.125/12.5)	(2.3/6.25)	(3.125/6.25)	(1250/1875)	(937.5/1250)	(56.25/75)		
CoNS	0.78-12.5	0.39-4.7	0.78-9.4	156.25-1250	312.5-1250	14.1-75		
	(3.125/6.25)	(1.56/2.3)	(1.56/12.5)	(625/1250)	(937.5/1250)	(56.25/75)		
Enterococcus spp.	3.125-6.25	3.125-6.25	3.125-4.7	625-1875	1250 -1250	56.5-75		
C. albicans	3.125	1.56	4.7	156.25	625	9.375		

* Range of MICs of BK against Pseudomonas isolates in mg/L.

** MIC₅₀ and MIC₉₀ of BK against *Pseudomonas* isolates in mg/L by cumulate and interpolate method.

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A strong correlations were based on the result of Spearman's correlation coefficients and these were recorded between the following pairs of biocides: CET and Dettol[®] (ρ 0.794, p<0.01, N=66); BK and Dettol[®] (ρ 0.791; p<0.01, N=66); PVPI and Dettol[®] (ρ 0.783; p<0.01, N=66); CET and PVPI (ρ 0.759; p<0.01, N=66); CHX and PVPI (ρ 0.721, p<0.01, N=66); CHX and Dettol[®] (ρ 0.599; p<0.01, N=66). The correlation coefficients revealed moderate but significant correlations between: CRA and PVPI (ρ 0.376; p<0.05, N=66); CRA and Dettol[®] (ρ 0.395; p<0.01, N=66). On the other hand, the correlations between CRA and the following biocides; BK, CHX and CET were low and insignificant at 0.05 level.

Furthermore, the MIC values of each of the tested biocides were correlated with the percentage of the resistant antibiotics to all isolates (calculated from the data presented in the supplementary tables) using Spearman's correlation. The correlation coefficients (**Table 3**) revealed moderate but significant (p<0.05) correlations between the percentage of the resistant antibiotics and the MICs of the following biocides: BK (ρ 0.278; p<0.05), CHX (ρ 0.376; p<0.01), CET (ρ 0.310; p<0.05) and PVPI (ρ 0.325; p<0.05). On the contrary, the correlations of the MICs of CRA and Dettol[®] with antibiotic resistance were low and insignificant at 0.05 level.

Discussion

The hospital environment is a potential reservoir of infectious agents since most patients carried normally in their intestine diverse pathogenic and highly resistant microorganisms. Moreover, the antibiotics, especially the broad spectrum types and the biocides are extensively used in hospitals [21]. This fact reflects why hospitals are suitable to examine the correlation between biocides susceptibility and antibiotics resistance among microoganisms.

The alarming increase in antimicrobial resistance rates among bacterial isolates is a real challenge currently facing the clinical practice in Egypt. Broad spectrum antibiotics such as aztreonam, carbapenems, third and fourth generation cephalosporins, penicillin/ β -lactamase inhibitors and quinolones are extensively and often empirically prescribed in the Egyptian hospitals. This may explain the occurrence of significant resistance to some broad spectrum antibiotics such as ceftriaxone and cefotaxime and the high prevalence of MDR among the isolates.

Although it has reported that the assessment of antibacterial activity of biocides by bactericidal testing is more relevant than bacteriostatic testing [4]. When a large number of strains are required for testing, the MIC determination is considered a

Table 3. Correlation between MIC	values of each biocide and	d the percentages of resistant a	antibiotics in
all screened isolates			

Spearman's Correlation Coefficient (၇)	P-value	N
0.278	0.03	61
0.376	0.003	61
0.310	0.015	61
0.215	0.096	61
0.325	0.011	61
0. 243	0.060	61
	Spearman's Correlation Coefficient (ρ) 0.278 0.376 0.310 0.215 0.325 0.243	Spearman's Correlation Coefficient (p)P-value0.2780.030.3760.0030.3100.0150.2150.0960.3250.0110.2430.060

P-value: Significance (2-tailed). N: degrees of freedom.

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time effective method [22]. In addition, it has been extensively used by many researchers for screening the biocide susceptibility of a large number of isolates [20, 22-26]. Agar dilution was the most convenient technique for MIC determination in the present work since most of the tested biocides; especially QACs, CHX and Dettol[®] produced cloudy precipitate in the culture media at relatively high concentrations (\geq 100 mg/L for QACs and CHX), whereas the inspection of the bacterial growth in liquid culture media by turbidity would be difficult to assessed [3, 22].

The ranges of MICs for the tested classes of organisms in this work were comparable to those obtained by other researchers [20, 23, 24]. For example, Koljalg et al. found that the range of CHX MICs for the Gram-positive isolates was much less than those of Gram- negative isolates. The non-fermentative bacteria; P. aeruginosa and A. baumannii isolates showed the highest CHX MIC and minimum bactericidal concentration (MBC) values among the 60 tested Gram-positive and Gram-negative isolates [27]. Since there was no definite international MIC breakpoints for biocides and those published in the literature were so variable, thus the interpretation of the obtained MIC values was considered relative to the MIC_{50} . A comparable approach was previously adopted by Kawamura-Sato et al. in determining the relative susceptibilities of the tested Acinetobacter isolates towards the biocides [20].

Most infection control practitioners emphasize the use of high concentrations of disinfectants according to their MICs. Generally, it is recommended that the in-use concentrations of disinfectants to be 100-1000 times greater than their MICs, since this method would prevent bacteria to overcome the rapid damage and to develop resistance [28]. Generally, QACs and CHX are used as aqueous or alcoholic solutions in hospitals. The in-use concentration of QACs is usually between 1100 - 2000 mg/L and that of CHX is often 5000 mg/L as reported by many studies [5, 20, 29]. These concentrations are generally used for hand hygiene and the disinfection of non-critical items including medical devices. In addition, this concentration of CHX is usually used in preoperative skin antisepsis [20]. The centres for Disease Control and Prevention in USA recommend 1:100 dilution of household bleach (hypochlorite solution) for disinfection in healthcare settings. This method would be equivalent to 500 mg/L [5]. It is reported that the best dilution of 10% povidone-iodine is 100 folds and this would be equivalent to 1000 mg/L [5]. The recommended dilutions of Dettol[®] by the manufacturer for medical uses are 1:20 for cuts and abrasions; and 1:40 for midwifery which is corresponding to 2400mg/L and 1200 mg/L , respectively.

Certain MICs in the present work, especially those for the non-fermentative Gram- negative isolates, were found to be very close to the recommended in-use concentrations of the biocides in hospitals. Therefore, the recommended 100 fold difference between the in-use concentrations and the obtained MIC values of the biocides were not achieved in many cases. The very strong and significant correlation between the MICs of BK and CET can be attributed to the fact that these two agents belong to the same class (QACs) on the basis of chemical structure and mode of action. The strong positive correlations between the QACs and CHX may be due to the similarity of their mechanisms of action, as both of them are predominantly membrane active agents. Similarly, significant positive correlations were obtained by Kawamura-Sato et al. who tried to correlate the MICs of different biocides for 283 clinical Acinetobacter isolates. The values of Spearman rank correlation coefficient were found to be 0.631 for BK and benzethonium chloride which is another QAC and 0.632 for BK and CHX gluconate. Both correlations were significant at 0.01 level [20].

The other high and significant correlations shown between different classes of biocides for which chemical structures and modes of action are

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dissimilar suggested that general rather than specific mechanisms of resistance may be involved in reducing biocide susceptibility showed by the MDR isolates.

The correlation between the MIC values of BK, CHX, CET, PVPI and the percentage of antibiotic resistant among the tested isolates revealed moderate positive correlations that ranged between 0.376- 0.278 and were significant at 0.05 level. However, the correlations of the MICs of CRA and Dettol® with antibiotic resistance were weak and insignificant. Similarly, Koljalg et al. found a good correlation between CHX and antibiotic susceptibilities in both Gram-negative and Gram-positive isolates, since the Spearman's correlation coefficients between the MICs of the investigated antibiotics and CHX susceptibility ranged between 0.32-0.67 [27]. The results of Kawamura-Sato et al. also showed that MICs of CHX and BK disinfectants were well correlated with three tested antimicrobial agents; ceftazidime, amikacin and ciprofloxacin (p < 0.05), and where the Spearman's correlation coefficients ranged between 0.336-0.189 [20]. Furthermore, Stickler et al. found strong significant positive correlations between MDR (tested by disc agar diffusion methods) and the MICs of three cationic antibacterial agents; CHX, CET and BK. Their correlation coefficients ranged between 0.7- 0.9 (p < 0.05). However, such correlation was not established with Hycolin® (a product containing chloroxylenol as active ingredient) [30].

Conclusions

The present study revealed a moderate positive correlation between antibiotic resistance and biocide tolerance among hospital bacterial isolates. This result should encourage the medical stuff in hospitals to be aware of the problem of cross-resistance between biocides and antibiotics, and the risk of developing resistance following inappropriate use of biocides dilutions.

There is no conflict of interest.

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